PERMIS'04 White Paper

PERMIS'04 Focuses on Measuring the Performance of Intelligent Systems.

A natural link and even lead emerges: not only to measure the Performance but also Measure the intelligence of Intelligent Systems and put both of them in correspondence. Measuring intelligence might become easy after a mathematical theory of intelligence is developed. However, for obvious reasons we need metrics before we can (and in order to) develop intelligent systems. One approach could be to list the properties of intelligence as far as we understand them and then to come up with qualitative measures for each. The overall model of intelligence might be obtained as a result of this problem-solving maneuver. Because there are a lot of these properties we need to come up with a hierarchy of them. Possibly this hierarchy (which, like intelligence itself, is not necessarily a strict hierarchy, but a heterarchy to some extent) could be a subject for the discussion.

A good starting point could be building a simplified provisional model of an "elementary intelligent agent (EIA)" (This model in its initial stage might include an internal model, sensors, perception, (re)cognition, behavior generator, actuators+ a hierarchy/heterarchy of these agents.) One can imagine an EIA even as a much simpler reduced set: perception and cognition are similar - just occurring at different hierarchical levels. A fundamental question: how are we going to represent EIA? Present possibilities include:

- pure mathematical model
- a descriptive model
- a model in terms of control theory
- linguistic model
- a model in terms of Information Technology

A next step could be characterization of the modules of EIA in terms of their relationships to the features of intelligence that are vaguely represented scientifically: concepts, emotions, thinking, learning, memories,... Can we come up with numerical characterization of each of these functions or at least a crisp descriptive characterization? How do they add to intelligence first, in terms of functions, second, in terms of efficiency, and third in satisfying our intuition about what is intelligence? Since various types of intelligence are being evaluated for humans, there similarly should be an array of types of intelligences for artificial systems.

The Goals of PERMIS'04

The goals of PerMIS'04 are to extend the body of knowledge pertaining to how to define, characterize, measure the intelligence of systems. There will be tracks emphasizing the theoretical developments in the area of performance measures and definitions relevant to intelligence and autonomy. These are complemented by tracks that focus on experimental results applied to domain-specific systems.

Examples of key themes for the theoretical tracks are listed here.

1. Evaluating Actionable Knowledge

This conference emphasizes metrics for evaluating the advanced methods of constructing the actionable knowledge from the data and information. The next problem would be: Actuation based on the Results of Intelligent Processing. Sensor development and data extraction with subsequent information acquisition (often called “getting the intelligence”) is only one part of enabling the Decision Support Processes accompanying the process of Actuation. Discovery and disambiguation of the system of interacting agents coordinated within the set of goals is the essence of knowledge construction required for the successful decision making and performing the expected functions of the system. It is critical to be able to define the quality of the knowledge – its uncertainty, resolution, precision, accuracy, etc. When constructing a model of the world, the system has to be able to weigh the relative merits of various inputs (clues) it receives as well as knowledge it already has.

2. Multiagent Intelligent Systems

Formulation or required behavior of multiple agents, and design of the action networks consistent with the realistic systems is the purpose in all domains of business and engineering application: from management support and drug discovery to robotics and military operations. Between data and actions there are processes of information extraction and knowledge construction required for behavior generation. Networks of knowledge, interwoven with intentional systems of goal oriented agents, ought to account for the available options in decision-making based upon knowledge, phenomenology and computational processes underlying the data and action. The knowledge repositories should not only contain the results of acquired data and information sets, they also must contain

- physical models of sensors or wave propagation and scattering
- chemical models of molecular interactions
- statistical models of object properties
- dynamical models of motion
- linguistic text models
- semiotic models of meaning
- cultural models of human behavior in the industry, or a society of interest.

3. Computations Pertained to Intellect

The challenge is to develop integrated intelligent computational systems capable of combining available data from the knowledge repositories, multiple disciplines, and the afforded sensors. Also corresponding to the stored knowledge, the models might be detailed or approximate, reflecting precisely known physical laws or uncertain intuitions about undiscovered phenomena or human nature. The integrated functioning of an intelligent system is not a one-time deal but a continuous loop of operations in which sensors and data collection are directed based on the current-moment results, models and actions are continuously refined. No wonder that the relevant systems have substantial affinity with the known architectures of Brain and Intelligence of living creatures. This resemblance will be explored at this conference.

4. Similar Algorithmic Structure

The conference focuses primarily upon areas important in the industrial environment, scientific research, business, and defense operations: integrated closed-loop operation of data acquisition→information extraction→knowledge construction→action. Components of this loop demonstrate similar algorithmic structure. All stages of this string employ tools and techniques of

- multiresolutional data, information, and knowledge analysis,
- entities discovery and recognition,
- exploratory large data arrays processing,
- signals and images analysis and interpretation,
- objects, scenes, and situation identification,
- design of efficient sensor systems,
- multimodal data fusion
- sensory and textual data fusion
- analysis of text messages
- natural language text interpretation
- integrated closed-loop operation

5. Domains of Application

These techniques are expected to be applied in the following domains

- intelligent transportation systems
- emergency response robots
- demining robots
- defense robotics
- command and control
- hazardous environment robots and control systems
- space robotics
- assistive devices
- automatic target recognition
- design of communication systems in the network-centric environment
- generation of the common operational picture in battlefield
- analysis of situations in business and industry
- gene profiling and development
- drug discovery
- manufacturing and process planning systems

6. Focal themes

The following fundamental ideas will be the focal themes at this conference:

- Models and Similarity Measures for Image Recognition
- Models and Similarity Measures for Text Interpretation
- Models and Similarity Measures for Situation Analysis
- Algorithms and Processes of Generalization
- Architectures of Intellect-like Computational Processes
- Search for Exploring Bodies of Data, Information, and Knowledge
- Hypotheses Generation and Disambiguation

7. Examples

The following are a few examples of major programs that rely on intelligent systems technologies and approaches. They are presented as a stimulus for workshop topics and discussion.

U. S. Army Future Combat Systems and Future Force Warrior

The Army is reinventing itself, aiming at lighter, more portable and lethal configurations. Robotic agents are a significant component within this new vision, dubbed Future

Combat Systems (FCS). Complementing this is the Future Force Warrior (FFW), described as "an integrated system of systems approach is being employed to support the Army transformation to a soldier-centric force. FFW notional concepts seek to create a lightweight, overwhelmingly lethal, fully integrated individual combat system, including weapon, head-to-toe individual protection, netted communications, soldier worn power sources, and enhanced human performance." [http://www.natick.army.mil/soldier/wsit/index.htm]

Physical agents, such as robotic weapons and sensor platforms, will be ubiquitous in the future battlefield, significantly lowering the risks to our warfighters. These physical agents are to complement future manned systems and therefore they must be able to collaborate not only amongst themselves but also with their manned partners. Their roles will range from scout missions performing reconnaissance, surveillance, and target acquisition to urban rescue missions. Information from both local and remote sensor systems will be fused by intelligent agents and provided to the dismounted warfighter in a highly intuitive form to enhance rapid assimilation and action. An integrated, multi-agent (software and physical) intelligent combat system will facilitate increased mobility, survivability, sensor coverage, information flow, and situation awareness. [http://www.peogcs.army.mil/future.cfm]

Logistics and Distributed, Modular Component-Based Systems

Of relevance to the military and to industry in general is the area of logistical planning. A key aspect of logistics planning and execution, involves reasoning about things, their properties, their relationships, and the activities in which these things participate. The things under consideration may generally be considered assets of one sort or another, and include equipment (e.g. radios, trucks, components, etc.), materiel (e.g. fuel, machine parts, food, etc.), facilities (e.g. road networks, airports, depots, etc.), varied types of organizations (i.e., civil, military and commercial organizations), and even individual people. In order to construct a computer system which participates in logistics planning and execution, it is necessary to have a mechanism to represent all the properties of assets required for logistics reasoning. Several aspects of these assets and their use in logistics systems make the problem hard: (1) The set of asset types and asset properties is very large. These asset properties must describe the forms and functions of each asset required for logistics reasoning. (2) The set of assets and properties evolves continuously over time as new models and types of equipment and materiel are continuously introduced, and older ones are retired. (3) Reasoning must be done over a range of granularities since varied amounts of detail are required at different locations and echelons in the logistics planning and execution processes. (4) Different portions of a logistic planning and execution system require different granularities specialized knowledge. [http://www.cougaar.org/] is one program that is focusing on development of an open source architecture for the construction of large-scale distributed agent-based applications.

Distributed and Multi-resolutional Knowledge Representation

A corresponding requirement for development of open, modular, intelligent logistical planning systems (and similar large scale systems) is the need for careful design of the knowledge representation. Assets must be carefully described; their properties updated as needed and made accessible to the concerned planning entities. As noted by the Cougaar program:

> “Given these principles which factor knowledge of logistics properties and behavior, we have been able to allow the detailed asset representation of any particular asset to differ depending on the perspective or interests or needs of the using agent. Thus, the instantiated aspects (properties or attributes) of an asset change as references to that same asset move throughout the society.”

The following are a few examples of agent roles and the corresponding property groups of interest for a truck asset. A transoceanic shipping company, which ships assets such as trucks, needs to know the physical dimensions of the trucks, and what is loaded on the trucks (if anything) while they are to be moved. A truck repair shop needs to know what is wrong with the trucks they have been contracted to repair, and what resources (parts, repair equipment, mechanical skills, time) will be needed to fix each truck. A ground shipping company which owns and operates fleets of trucks needs to know such things as what cargo is on board its trucks, where its trucks are going, how much fuel is in its trucks’ fuel tanks, and when its trucks will be out of service for scheduled maintenance or repair.”

The different, parallel views of the same asset must be crafted to provide the right information for reasoning by the different interested systems. How to design, evaluate, and ensure the validity of the knowledge representation is an extremely significant aspect within the science of intelligent systems.

8. Workshop Format

Researchers from academia, commerce, and defense research centers will exchange ideas and program managers will inform on the directions of research and development. The workshop will consist of plenary lectures, panel discussions, and concurrent forcussed session where papers are presented and discussion is encouraged. Two social events are planned: a reception on Tuesday night and a banquet with special speaker on Wednesday night.